

FLORIDA STATE UNIVERSITY
BINAURAL BEATS: THEIR PERCEPTION BY INDIVIDUALS
WITH AND WITHOUT ORGANIC BRAIN PATHOLOGY

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One of the primary functions of the clinical psychologist is to aid in the diagnosis of mental disease. Within this area, a fundamental differentiation to be made is between functional and organic pathology. The latter has been reported by the National Mental Health Committee (1956) as comprising more than one-third of all new admissions to public mental hospitals. Admittedly a serious problem now, it portends to become increasingly so with the continuing extension of the life span with the concomitant dangers of senile psychosis and arteriosclerosis (Committee on Hospitals Group for Advancement of Psychiatry, 1950). Since effective treatment often depends upon the accurate and early detection of this pathology and since the neurological examination and electroencephalogram often fail to detect many such cases (Hodamaker & Murray, 1952), psychological testing as an adjunct to them, or as a screening procedure is of considerable importance.

A wide variety of specific tests for organicity is in use and many of the general tests, such as the Rorschach and Wechsler-Bellevue, have their indices for this impairment. Evaluations such as those by Armitage (1946) and Yates (1954) point out the shortcomings of many of the more popularly used tests in terms of their validity, ease of administration and other factors, so the need for extension of our means of differentiation remains distinct.

In addition to these formal psychological tests, perceptual differences have been noted between brain injured and normal persons in studies of flicker perimetry, apparent motion, double simultaneous

stimulation, reversible figures and a variety of other tasks, the results of which have been reviewed by Teuber (1945). Thus far, but one of these, the Archimedes spiral after-image, has been standardized and applied as a means of diagnosing organic brain pathology (Price & Deabler, 1955). It should be noted that this test, as well as the vast majority in clinical use, relies upon visual perception.

Efforts to determine the effect of brain lesions upon hearing have largely been limited to a comparison of the audiograms of patients with and without this condition. Northington (1936) examined 52 patients with verified intracranial tumors, and found no conclusive evidence of impaired hearing. McNally, Erickson, Scott-Moncrieff and Reeves (1936) reported a similar conclusion after testing 14 patients with varying degrees of cerebral tissue removed by surgery. Saltzman (1952), however, found that six of 12 patients having post-operative mesencephalic and thalamic lesions showed a significant audiometric change, primarily in the form of a contralateral high tone loss. Bordley and Hoskins (1955) compared audiograms established subjectively and by psychogalvanic skin response (PSGR) with the same patients, and suggested that in those instances of good hearing by PSGR but poor subjective hearing, probable damage to the cerebral cortex was involved.

Only two attempts to assay the role of organic pathology in higher auditory functioning were described in the literature. Werner and Bowers (1941) noted characteristic failures on the part of brain injured children in their ability to vocally reproduce melodic patterns presented to them on the piano. Miller (1945) prepared phonograph records with ambiguous or "reversible" melodies, which could be structured by the listener in either of two ways. Systematic modifications of the

tonal patterns made one or the other structure more compelling. The impairment of the ability to effect auditory figure-ground reversals was considered as a possible cue to brain injury. In its original form, however, the test is thought to be too difficult to be useful.

Prior to 1956, then, no sufficiently valid test for organicity using hearing, or sense modalities other than vision, in fact, had evolved.

The familiar, easily perceived, binaural beat (BAB) phenomenon has long been the subject of extensive investigation. A representative description of BABs by Wever (1929, p. 158), states that "if two tones differ but little in frequency and their intensities are somewhere near equal we hear peculiar surgings of sound known as beats which become increasingly rapid as the tones are made to differ more in frequency." He distinguished three stages of BABs appearing successively as the beat frequency increases from zero upward: (a) noticeable oscillations or surges. (b) intermittence or pulsation. (c) roughness without intermittence.

As early as 1894, the possibility of the central (versus the peripheral) origin of the BAB phenomenon had been considered (Ewald, 1894). Peterson (1916), Boring (1926) and Jorgensen (1948) are representatives of this view, describing BABs as arising when the neural impulses from both ears are joined in a common neural center. Chocholle (1947) similarly emphasized a central integrative process, with BABs arising both from the convergence of afferent impulses upon a common center, and the interaction of adjacent neurones.

Boring (1926, p. 161) offers an additional explanation for the roughness noted at higher beat frequencies which suggests a basis

different from the synchrony associated with the surges or pulsations noted at lower beat frequencies. He states that "roughness can be regarded simply as a fluctuation of the output of the common center at a rate faster than the higher neural centers can readily follow."

On the basis of the suggested role of higher central nervous system integrative function in the perception of BABs, and the possibility that damage to the brain might disrupt this function, a comparison of the ability of subjects (Ss) with and without brain damage in perceiving BABs seemed warranted. Since this would involve a "heard" and "not heard" categorization of responses, Boring's comment (1926) regarding the differential process involved in the perception of BABs as roughness indicates the necessity of a two-level definition of beats, one of which would exclude this aspect.

A pilot study based upon two such definitions of beats, and the frequency ranges over which they were heard, encouraged the additional research reported in this dissertation, in which the following hypotheses were tested:

Hypothesis I. Assuming the null hypothesis, no true difference is expected in the frequency with which the normal and chronic brain syndrome (CBS) groups report BABs as noticeable oscillations or surges, and/or intermittence or pulsation (Definition 1).

Hypothesis II. Assuming the null hypothesis, no true difference is expected in the frequency with which the normal and CBS groups report BABs as noticeable oscillations or surges and/or intermittence or pulsation and/or roughness without intermittence (Definition 2).

Hypothesis III. Assuming the null hypothesis, no true difference is expected between the normal and CBS groups in the average frequency at

which BABs were reported as defined by Definition 1.

Hypothesis IV. Assuming the null hypothesis, no true difference is expected between the normal and CBS groups in the average frequency at which BABs were reported as defined by Definition 2.

Hypothesis V. Assuming the null hypothesis, no true difference is expected between the normal and CBS groups in the average range over which BABs were reported as defined by Definition 1.

Hypothesis VI. Assuming the null hypothesis, no true difference is expected between the normal and CBS groups in the average range over which BABs were reported as defined by Definition 2.

To afford a standard of comparison with a satisfactorily valid, reliable, widely used test for organic brain damage, the Graham-Kendall Memory-for-Designs Test (GK) was utilized (Graham & Kendall, 1946). This test involves having the S view a series of cards, each with a geometric design on it, and attempt to reproduce these designs by drawing shortly after each card is taken away. A score of 12 or more is described by the authors of the test as indicative of organicity.

Since the gathering of data for this research, there have been several pertinent publications (Sanchez-Longo & Forster, 1958; Matsker, 1959), including the results of a follow-up study by Price, Garrett, Hardy & Hall (1958) based upon this investigator's work.

Using 50 Ss having the diagnosis of CBS and 50 normal Ss, Price, et al (1958) compared performances of the GK, Archimedes spiral after-image test, and the ability to perceive BABs. The validity of each of these methods as a test for CBS was supported by the findings.

Sanchez-Longo and Forster (1958) studied the ability of 50 patients with brain tumors to localize "white noise" signals. Those

with temporal lobe lesions identified the sound source as displaced to the side opposite the lobe in which the tumor occurred. No such distortion was found when the lesions were in other cerebral regions.

Using pure tone signals over a range of frequencies, and presenting them at interaural time differences to simulate their originating from various directions, Matsker (1959) evaluated 400 brain tumor patients. Abnormal lateralization of sound was not limited to temporal lobe involvement, but included pathological processes of the frontal, parietal and occipital lobes as well.

In addition to these modifications of Sanchez-Longo and Forster's (1958) technique, Matsker (1959) described an original method of identifying organic brain damage making use of a binaural process. Phonetically balanced words were separated into their high and low frequency components by filters, and each sent to an individual headphone. Persons without brain damage experienced a binaural fusion that made the word recognizable. Of the 1700 patients tested by this procedure, defective binaural fusion (reflected by the words seeming unintelligible) characterized the majority of those with brain damage. As a result of the application of this test, and the opportunity to complete several autopsies of previously tested patients, Matsker (1958, p. 1190) concluded, "It appears therefore that the binaural test is a reliable indicator of the extent to which ganglionic cells within the brain stem are out of operation." He cited this physiological loss of ganglionic cells as an aging process, and expressed his belief that this accounted for the rather consistent failure of his Ss over 65 years of age to fuse words binaurally.

Matsker's notation on the influence of age in the binaural process encouraged the evaluation of the Ss used in this BAB perception research.

Unfortunately, the limited sizes of the participating groups did not provide a sufficient number of Ss above the 65 year level noted by Matsker (1958) to support sound statistical procedure, so a wider interval was used.

Based upon this, the final hypotheses are as follows:

Hypothesis VII. Assuming the null hypothesis, no true difference is expected between the 20-49 year old group and 50-69 year old group in their ability to perceive BABs as defined by Definition 1.

Hypothesis VIII. Assuming the null hypothesis, no true difference is expected between the 20-49 year old group and the 50-69 year old group in their ability to perceive BABs as defined by Definition 2.

Method

Subjects

The CBS group consisted of 26 male patients in the Biloxi Veterans Administration Center and the Gulfport Veterans Administration Hospital. They ranged from 21 through 69 years, with an average age of 48 years 11 months. Each carried a current diagnosis of CBS (See Table 1) as defined in the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association Mental Hospital Society, 1952), and established by medical procedure rather than psychological tests. The latter precaution was taken to avoid biasing this group through the in-

Insert Table 1 about here

clusion of Ss who had already demonstrated test behavior typical of the brain injured, particularly on the GK which was often included in psychological evaluations at these VA centers.

The normal group was comprised of 30 persons with no known history of intracranial organic pathology. Two were women, 28 men, and they ranged from 21 through 69 years with an average age of 45 years 9 months. Of the women, one was a secretary, the other a nurse. Five of the men were attendants, 23 were hospital and domiciliary patients. All were from the Biloxi VA Center.

Subjects in both groups had been screened by an audiometric examination, and met a criterion of being able to hear a 256 cycle per

second (cps) signal of 30 decibel's (deb) intensity, and revealed no more than a 10 deb difference in sensitivity between their ears.

Apparatus

A Maico E-2 audiometer was used in a sound-proofed room for the audiometric examination.

In testing for the ability to perceive BABs, use was made of separate tone signals independently generated by a pair of recently calibrated 115-volt Army Air Force TS 382-A/N variable audio oscillators. The signals produced were fed to a pair of dynamic headphones mounted on "doughnut" sockets supported by headbands. A signal intensity of 57 deb was utilized, having been found to overcome extraneous noise, yet insufficient to be heard in other than the ear to which presented.

Procedure

Each person given the audiometric examination was informed that it was a check of his hearing. Seated facing away from the apparatus to eliminate visual cues to the signal presentation, the S was told, "Whenever you hear the tone, say 'yes' to let me know."

The frequency of the signal presented was 256 cps - the closest setting available to that used in examining for the beat phenomenon. A signal of one second's duration was used at each five deb step in the descending series starting at 60 deb and the ascending series starting at zero deb. The sequence followed was a descending and ascending series to the right ear, descending and ascending series to the left ear, then a repetition of these series. Those Ss who met the criterion established for sensitivity were told they would be called in for the second part of the hearing check.

In testing for BABs, a frequency of 250 cps was used as the fixed test frequency, being well within the range described by Lidlicker, Webster and Hedlum (1950) as yielding easily perceptible beats. Concomitantly, an exploratory tone was varied over the range from 200 to 300 cps providing a margin of approximately 20 cps above and below the range over which BABs can be heard under optimal conditions.

The S was told, "This is another part of that check of your hearing. This time I want you to keep telling me exactly what you hear." These directions in combination with the seeking of clarification had been found in a pilot study to elicit comprehensive descriptions in the great majority of cases. For those who did not spontaneously cover these qualities in their initial description of what they heard, participation was encouraged by asking whether they heard one tone ("buzz," etc., whichever term they use) or more than one, and what it (they) was (were) doing. This proved sufficient to effect closer descriptions from the few who required its use.

The S's verbal description of what he heard and at which frequency was recorded. At the end of each series he was told, "Now I'm going to make some changes. Keep telling me exactly what you hear. Go ahead." The setting was slowly and smoothly changed, spanning the 100 cps in approximately two minutes, pausing whenever the S requested it. If, at any time, a change of more than 20 cps occurred without a verbal report, he was asked, "What do you hear now?" The series followed for all Ss consisted of: (a) presentation of a fixed 250 cps signal to the right ear, the signal to the left ear covering from 300 to 200 cps. (b) presentation of a fixed 250 cps signal to the right ear, the signal to the left ear covering from 200 to 300 cps. (c) presentation of a fixed

250 cps signal to the left ear, the signal to the right ear covering from 300 to 200 cps. (d) presentation of a fixed 250 cps signal to the left ear, the signal to the right ear covering from 200 to 300 cps.

All Ss noted that one signal was fixed, and the other was being varied. For those Ss reporting fluctuations of an additional tone in terms other than the pulsing, waving, oscillating, surging periodic up and down sound characteristic of Definition 1 and the roughness included in Definition 2, clarification was sought through presentation of two more ascending and descending series.

In the first, they were directed, "Now I want you to listen for a wavy, pulsating, up and down sound. Tell me when you hear it." With the second, "Now I want you to listen for a rough sort of sound. Tell me when you hear it." When the Ss spontaneously identified the correspondence of terms, or reported them over the same frequencies at which they had previously described the effect, the terms were accepted as equivalent.

Also, those Ss who were classified as not hearing BABs, describing only the fixed and ascending or descending signals, were given the additional two series to determine whether or not they had heard another effect which they had not reported. Their responses to these added series did not change their assignment to the "not heard" category, but were solely for the purpose of determining a possible inability to describe the BAB phenomenon, although heard.

Immediately after the completion of the testing for BABs, the GK was administered following standard directions. Several months later, the protocols were scored by the usual method of comparison with drawings in the manual (Graham & Kendall, 1946).

Results

The Ss readily appeared to understand the instructions, and the vast majority provided a nearly continuous account of what they heard. For those who occasionally lapsed into silence, the experimenter's (E) query, "What do you hear now?" was sufficient to re-effect involvement.

All Ss paid close attention to the signals, and there were no expressions of inadequacy or failure in contending with the task presented. One S in the CBS group, however, did complain that the sound made him "nervous." Upon exploration of his feelings, he revealed having received electroshock therapy years before, and expressed his belief that the oscillators provided an unpleasant reminder of the shock-producing apparatus.

For those Ss who reported more than the fixed and varying tone in each series, the additional tone arising from the interaction was readily noted. The majority of Ss used terms that easily confirmed their perception of the BAB phenomenon. The follow-up series effectively clarified the remainder. Table 2 lists the frequency of the descriptions used by Ss which were found to indicate the pulsations, surges or oscillations of BABs.

Insert Table 2 about here

The descriptions which were found to be indicative of the roughness aspect of BABs involved in the broader Definition 2 are enumerated

in Table 3. Some Ss used more than one term to qualify what they heard

 Insert Table 3 about here

and these are listed in the table. Others contributed terms to the vocabulary in both Tables 1 and 2 since they perceived both aspects of BABs. Note that "humming" is the only description appearing in each list, in one instance being clarified as equivalent to roughness, in another equivalent to pulsating. Therefore, the vocabulary involved in the two levels of definition of BABs appears to be distinctive.

A comparison of the ability of normal and CBS Ss to perceive BABs as defined by Definition 1 is presented in Table 4. Seventy-seven per cent (23Ss) of the normal group, and 12% (3Ss) of the CBS group perceived

 Insert Table 4 about here

BABs by this criterion. A chi-square analysis based upon the number of Ss in each category is significant beyond the .001 level of confidence. Hypothesis I, stating that no true difference is expected in the frequency with which the normal and CBS groups report BABs as noticeable oscillations or surges, and/or intermittence or pulsation (Definition 1) is accordingly rejected.

Table 5 presents a similar comparison using Definition 2 for BABs.

 Insert Table 5 about here

Ninety per cent (27Ss) of the normal group, and 23% (6Ss) of the CBS

group heard BABs by this criterion, the inclusion of roughness qualifying four more normal Ss and three more CBS Ss as having perceived this phenomenon. A chi-square analysis of these results is significant beyond the .001 level of confidence. Hypothesis II, which states that no true difference is expected in the frequency with which the normal and CBS groups report BABs as noticeable oscillations or surges and/or intermittence or pulsation and/or roughness without intermittence (Definition 2) is also rejected.

A comparison of the average frequency and range at which normal and CBS Ss heard BABs by Definition 1 is presented in Table 6, and similar measures for BABs by Definition 2 appear in Table 7.

 Insert Tables 6 and 7 about here

From Table 6, the 23 normal Ss heard BABs at an average frequency of 253.5 cps, and the three CBS Ss at an average frequency of 251.9 cps. A t-test between these averages proved non-significant. Hypothesis III, stating that no true difference is expected between the normal and CBS groups in the average frequency at which BABs were reported, is accepted.

Similarly (See Table 7), a t-test between the 253.4 cps average frequency at which BABs were heard by the 27 normal Ss, and the 251.3 cps average for the six CBS Ss is non-significant, leading to the acceptance of Hypothesis IV, that no true difference is expected between the normal and CBS groups in the average frequency at which BABs were reported as defined by Definition 2.

The ranges over which the normal Ss perceived BABs by Definition 1 (See table 6) are 34.12 cps and 33.33 cps. Non-significance between

these averages was demonstrated by the t-test, leading to the acceptance of Hypothesis V, that no true difference is expected between the normal and CBS groups in the average range over which BABs were reported as defined by Definition 2.

Table 7 indicates that the average range over which the 27 normal Ss heard BABs was 35.26 cps, and that for the six CBS Ss was 54.30 cps. The latter broadening of the range was through the inclusion of two additional Ss reporting only roughness over the entire range of 200-300 cps presented to them.

The t-test between these averages is significant beyond the .01 level. Hypothesis VI, stating that no true difference is expected between the normal and CBS groups in the average frequency over which BABs were defined by Definition 2, is rejected.

The Graham-Kendall test was able to accurately diagnose 77% or 20 of 26 in the CBS group. This is comparable to the 88% (See Table 4) and the 77% (See Table 5) of the same group who were unable to perceive BABs by Definition 1 and Definition 2 respectively. Of the six CBS Ss missed by the GK, two were totally unable to report BABs.

On the other hand, the three CBS Ss hearing BABs by Definition 1 similarly failed to earn a score in the organic range on the GK, while one of the additional three Ss hearing BABs by Definition 2 would have accurately been identified as organically impaired on the GK.

Tables 8 and 9 compare Ss from both groups comprising a 20-49 year age range with those in the 50-69 year range in their ability to hear BABs by Definitions 1 and 2.

 Insert Tables 8 and 9 about here

In Table 8, 16 of the 26 Ss in the 20-49 year group and 10 of 15 Ss in the 50-69 year group heard BABs by Definition 1. A chi-square analysis of these results is non-significant, leading us to accept Hypothesis VII, which states that no true difference is expected between the 20-49 year old group and 50-69 year old group in their ability to perceive BABs as defined by Definition 1.

Applying Definition 2, Table 9 reveals that 18 Ss in the 20-49 year group, and 15 of 15 Ss in the 50-69 year old group reported BABs. A chi-square analysis of these results also proved non-significant, leading to the acceptance of Hypothesis VIII, that no true difference is expected between the 20-49 year old group and the 50-69 year old group in their ability to perceive BABs as defined by Definition 2.

Discussion

The ability to perceive BABs was found to be significantly related to organic brain pathology in that non-brain damaged Ss tended to experience BABs while brain damaged Ss did not. That this was a function of perceiving and not perceiving, rather than reporting and not reporting, was established by the follow-up series which instructed the S what to listen for, providing an opportunity for even the most inarticulate to acknowledge BABs if he experienced them. No S was added to the "Heard" category due to this series.

The compilation of descriptions used by the Ss and the establishment of their equivalence to surges, pulses, oscillations (See Table 2), or the roughness (See Table 3) incorporated in Wever's (1929) definition of BABs, revealed distinct differences between categories that allowed adequate separation of Definitions 1 and 2 with only a one word overlap. While most of the descriptions could have been correctly categorized by the E when initially presented, the clarification of the terms by use of the supplementary series allowed greater assurance of accuracy. This precaution is worth including in any exploration of the BAB phenomenon through the method of verbal report in that idiosyncratic use of a descriptive term is occasionally encountered.

A division of Wever's (1929) definition of BABs to include or exclude roughness because of its possible relationship to organicity did not show one criterion to be superior to the other as a predictor of a S's belonging to the normal or CBS group. The nearly equal relevant

values for chi-square (Tables 4 and 5) reflect this. Broadening the definition to include those Ss hearing only roughness merely added equally to those rated as having heard BABs in both groups.

No distinctive differences were demonstrated between normal and CBS Ss in the average frequency and range over which they perceived BABs (Tables 6 and 7), with the exception of the wider, more variable average range noted for the six CBS Ss hearing BABs under Definition 2. The range and variability was strongly influenced by two Ss who heard roughness over the entire frequency range. This may be a consequence of organicity but was not encountered sufficiently often in this group to confirm its value as a diagnostic cue. An intensive evaluation of such Ss would be of value in clarifying the correlates of their unique BAB perception.

Price, Garrett, Hardy and Hall's (1958) research employing a test for the BAB phenomenon as well as using the GK and spiral after-image test was based on the research reported herein. However, it includes an important difference that must be taken into account before a comparison can be made: their brain damaged Ss had CBS diagnoses plus "organic" range scores on either the spiral after-image or GK test; and their non-brain damaged Ss had achieved "normal" range scores on both of these tests. The resultant quantification of the effectiveness of the GK and spiral after-image tests to diagnose brain damage would probably be higher than if the participants in these groups had been selected without psychological testing, as was the case in the research reported in this dissertation. As it was, the GK was 88% effective, the spiral after-image 84% effective and the ability to perceive BABs 76% effective in identifying those with brain damage.

The criterion used by Price, et al (1958) for perceiving BABs was based upon having the S point to whichever one of three simple line drawings on a card most closely approximated what he heard. The first was a straight line (the tone signal); the second a sinusoidal curve (oscillations or surges); the third, a series of straight dashes (intermittence or pulsation). Since no line depicting roughness was used, the sinusoidal and interrupted lines correspond to this E's Definition 1. The 49 normal Ss (98%) and 12 CBS Ss (24%) who perceived BABs in their study, therefore compare with the 23 normal Ss (77%) and three CBS Ss (12%) perceiving BABs in this E's research. If this E similarly imposed a GK test score criterion, retaining only those Ss in the normal group earning a "normal" range GK score and those in the CBS group earning an "organic" range score, 100% (20Ss) of the brain damaged group and 89% (23Ss) of the normal group would have been accurately identified.

Price, et al (1958, p. 216) concluded that:

The report of perception of BAB phenomena is a valid test for diagnosis of cortical brain impairment. It is assumed that the perception and reporting of this auditory phenomena are dependent upon the integrative function of the cerebral cortex. Organic impairment is believed to bring about a reduction of this integrative function similar to that occurring in the perception of apparent motion and related phenomena.

The only other binaural test for brain damage is a recent innovation by Matzker (1959) involving fusion of word components. Eighty-four per cent of patients with cerebral tumors in all regions, 68% of patients with cerebral atrophy, 46% of hypertensive patients, 35% of multiple sclerotic patients and 30% of skull trauma patients were diagnosed as having intracranial organic pathology by this technique. The most unique aspect of this test involves its seeming specificity for

damage to the brain stem. Histological evidence was presented to support this belief.

Since the word-fusion and BAB tests share binaural integration as a central feature, it would be desirable to determine their comparability, and especially important to explore the possibility that BAB perception might display a similar specificity for brain stem damage.

The sharp increase of pathological performances noted by Matzker (1959) as occurring in persons over the age of 65 "nearly without exception" had no demonstrable counterpart in this E's research. However, the grossness of the categories used did not allow a thorough evaluation of the influence of age.

This experiment demonstrates that perception of the BAB phenomenon is a valid test for brain damage with sensitivity comparable to that of the GK. It has the advantage of relative ease of administration, takes little time, is sufficiently compelling to offset distractibility, and appears to minimize any sense of inadequacy or failure in the participants. It would be uniquely suitable for testing blind persons who would not be able to take the more commonly used tests involving vision. Also, it would be applicable to those persons with neuromuscular impairment who could not participate in tests such as the GK which involve drawing. Persons with muteness or other impairment of verbal expression could also be tested for BAB perception through the application of Price, Garrett, Hardy and Hall's (1958) line drawings depicting wave forms.

Summary

Twenty-six brain damaged and 30 non-brain damaged, audiometrically screened 20 to 69 year old Ss were compared in their ability to perceive BABs using a fixed 250 cps and varying 200 to 300 cps oscillator-produced signals. Seventy-seven per cent of the non-brain damaged Ss were able to describe the equivalent of oscillations, surges or pulsations while 88% of the brain damaged group were unable to experience this perception. The GK identified 77% of the brain damaged Ss. Average frequency and range over which beats occurred and the influence of age were evaluated and not found significant. It was concluded that the ability to perceive BABs was a valid test for brain damage with a unique potential for testing persons with blindness and neuromuscular impairment.

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Table 1
Diagnostic Composition of
Chronic Brain Syndrome Group

Diagnosis	Number
CBS associated with brain trauma	5
CBS associated with cerebral arteriosclerosis	6
CBS associated with circulatory disturbance other than arteriosclerosis	2
CBS associated with central nervous system syphilis	1
CBS associated with circulatory disturbance, thrombus	1
CBS associated with intoxication (Korsakoff's Syndrome)	1
CBS associated with alcohol intoxication	1
CBS of unknown cause	<u>2</u>
Total	26

Table 2
 Frequency of Descriptions used by Normal and Chronic
 Brain Syndrome Subjects to Describe Surges, Pulses
 or Oscillations of Binaural Beats

Description	Frequency of Usage	
	Normal Group	CBS Group
Wave, waving, wavery, etc.	10	2
Up and down	6	0
Buzzing	3	0
Pulse, pulsing	3	0
Beat, beating	2	0
Irregular	2	0
Uneven	2	0
Bubbling	1	0
Discord	1	0
Disharmony	1	0
Dissonant	1	0
Flickering	1	0
Flutter	1	0
Humming	1	0
Jerks	1	0
Rising and falling	1	0
Quivering	1	0
Throbbing	1	0
Unlevel	1	0
Vibrating	1	0
(Mimics oscillating sound)	3	0
(Illustrates by waving hand)	3	0

Table 3
 Frequency of Descriptions used by Normal and
 Chronic Brain Syndrome Subjects to Describe
 the Roughness Aspect of Binaural Beats

Description	Frequency of Usage	
	Normal Group	CBS Group
Roar, roaring, etc.	6	3
Rough	2	0
Coarse	1	0
Drumming	1	0
Humming	1	0
Ringling	1	0
Rolling	1	0

Table 4

Comparison of Normal and Chronic Brain Syndrome
 Subjects' Ability to Perceive Binaural Beats
 (Defined as noticeable oscillations or surges
 and/or intermittence or pulsations)

Binaural Beats	Group		Chi-square	<u>P</u>
	Normal	CBS		
Heard				
N	23	3		
%	77	12		
Not Heard				
N	7	23		
%	23	88		
			23.9	.001

Table 5

Comparison of Normal and Chronic Brain Syndrome

Subjects' Ability to Perceive Binaural Beats

(Defined as noticeable oscillations or surges and/or intermittence
or pulsation and/or roughness without intermittence)

Binaural Beats	Group		Chi-square	P
	Normal	CBS		
Heard				
N	27	6		
%	90	23		
Not Heard				
N	3	20		
%	10	77		
			22.7	.001

Table 6

Average Frequency and Range over which Normal and Chronic
Brain Syndrome Subjects Perceived Binaural Beats
(Defined as noticeable oscillations or surges
and/or intermittence or pulsation)

	Normal	CBS	T-Test	P
N	23	3		
Mean Frequency	253.5	251.9		
SD Mean Frequency	5.67	0.88		
			0.36	—
Mean Range	34.12	33.33		
SD Mean Range	5.46	13.58		
			0.19	—

Note.— Frequency and range in cycles per second.

Table 7

Average Frequency and Range over which Normal and Chronic
Brain Syndrome Subjects Perceived Binaural Beats
(Defined as noticeable oscillations or surges and/or intermittence
or pulsation and/or roughness without intermittence)

	Normal	CBS	T-Test	<u>P</u>
N	27	6		
Mean Frequency	253.4	251.3		
SD Mean Frequency	5.72	1.11		
			0.47	—
Mean Range	35.26	54.30		
SD Mean Range	4.45	10.08		
			17.8	.01

Note.- Frequency and range in cycles per second.

Table 8
 Age Level and Ability to Perceive Binaural Beats for
 Combined Normal and Chronic Brain Syndrome Groups
 (Defined as noticeable oscillations or surges
 and/or intermittence or pulsation)

Binaural Beats	Age Range		Chi-square	P
	20-49	50-69		
Heard	16	10		
Not Heard	15	15		
			.742	—

Table 9

Age Level and the Ability to Perceive Binaural Beats for
 Combined Normal and Chronic Brain Syndrome Groups
 (Defined as noticeable oscillations or surges and/or intermittence
 or pulsation and/or roughness without intermittence)

Binaural Beats	Age Range		Chi-square	<u>P</u>
	20-49	50-69		
Heard	18	15		
Not Heard	13	10		
			.267	—